

Comparison of Home Lead Dust Reduction Techniques on Hard Surfaces: The New Jersey Assessment of Cleaning Techniques Trial

David Q. Rich,^{1,2} George G. Rhoads,¹ Lih-Ming Yiin,¹ Junfeng Zhang,¹ Zhipeng Bai,^{1,3} John L. Adgate,⁴ Peter J. Ashley,⁵ and Paul J. Liroy¹

¹Environmental and Occupational Health Sciences Institute, University of Medicine and Dentistry of New Jersey, Robert Wood Johnson Medical School and Rutgers University, Piscataway, New Jersey, USA; ²Environmental Epidemiology Program, Departments of Epidemiology and Environmental Health, Harvard School of Public Health, Boston, Massachusetts, USA; ³College of Environmental Science and Engineering, Nankai University, Tianjin, China; ⁴Division of Environmental and Occupational Health, University of Minnesota School of Public Health, Minneapolis, Minnesota, USA; ⁵Office of Healthy Homes and Lead Hazard Control, U.S. Department of Housing and Urban Development, Washington, DC, USA

High efficiency particulate air filter (HEPA) vacuums, which collect particles > 0.3 μm , and trisodium phosphate (TSP), a detergent claimed to selectively remove lead, have been included in the HUD *Guidelines for the Evaluation and Control of Lead Based Paint Hazards in Housing* without systematic validation of their effectiveness. At the time the study was initiated, both HEPA vacuums and TSP were relatively expensive, they were not readily found in urban retail centers, and there were environmental concerns about the use and disposal of high-phosphate detergents. A randomized, controlled trial was conducted in urban high-risk homes in northern New Jersey to determine whether a more readily available and less expensive low-phosphate, non-TSP detergent and non-HEPA vacuum could perform as well as TSP and a HEPA vacuum in a cleaning protocol. Homes were randomized to one of three cleaning methods: TSP/HEPA vacuum, TSP/non-HEPA vacuum, or non-TSP/non-HEPA vacuum. Change in log-transformed lead loading was used in mixed models to compare the efficacy of the three cleaning techniques separately for uncarpeted floors, window sills, and window troughs. After we adjusted for baseline lead loading, the non-HEPA vacuum produced larger reductions on hard floors [19%; 95% confidence interval (CI), 3–38%], but the HEPA vacuum produced larger reductions on window sills (22%; 95% CI, 11–32%) and larger reductions on window troughs (16%; 95% CI, –4 to 33%). The non-TSP produced larger reductions on window troughs (21%; 95% CI, –2 to 50%), but TSP produced larger reductions on hard floors (5%; 95% CI, –12 to 19%) and window sills (8%; 95% CI, –5 to 20%). TSP/HEPA produced larger reductions on window sills (28%; 95% CI, 18–37%) and larger reductions on window troughs (2%; 95% CI, –24 to 23%), whereas the non-TSP/non-HEPA method produced larger reductions on hard floors (13%; 95% CI, –5 to 34%). Because neither vacuum nor detergent produced consistent results across surface types, the use of low-phosphate detergents and non-HEPA vacuums in a temporary control measure is supported. **Key words:** cleaning, Department of Housing and Urban Development, HEPA, lead, trisodium phosphate. *Environ Health Perspect* 110:889–893 (2002). [Online 24 July 2002] <http://ehpnet1.niehs.nih.gov/docs/2002/110p889-893rich/abstract.html>

Numerous studies have identified house dust as a major pathway by which children are exposed to lead (1–3), including a pooled analysis that demonstrated that this relationship existed at dust lead levels considerably below the old U.S. Department of Housing and Urban Development (HUD) postabatement clearance standards and the U.S. Environmental Protection Agency's (EPA) guidance levels (100, 500, 800 $\mu\text{g}/\text{ft}^2$ for floors, sills, and wells, respectively) (4). Since then, both HUD and the U.S. EPA have revised their floor and window clearance-risk assessment standards to 40 and 250 $\mu\text{g}/\text{ft}^2$ respectively, with a clearance standard of 400 $\mu\text{g}/\text{ft}^2$ being retained for window troughs (5,6).

Charney et al. (7) demonstrated that postabatement dust reduction efforts reduced blood lead levels by 18% in a cohort of children with a mean blood lead of 39 $\mu\text{g}/\text{dL}$. Liroy et al. (8) showed that a regular biweekly professional cleaning can significantly decrease lead levels in carpets, sills, and other

household surfaces. In a randomized trial in toddlers with mean blood lead of 12 $\mu\text{g}/\text{dL}$, Rhoads et al. (3), using data from the same study, showed that maternal education and these biweekly cleanings produced a 17% decline in blood lead on average, compared to no change in control children. Other trials examining cleaning effectiveness that showed no significant decrease in blood lead levels after cleaning either only provided cleaning supplies and educational materials and did not guarantee that cleaning occurred (9,10) or were done in an active smelter community with more modern housing (11). The studies that have provided actual cleaning of urban homes suggest that not only does regular cleaning reduce dust lead levels, but it also directly reduces blood lead levels.

The HUD guidelines provide cleaning protocols for two situations involving the control of lead based hazards: a temporary, interim dust control measure (two-step cleaning process), and a cleanup following lead

hazard reduction interventions (three-step cleaning process). The two-step process was assessed in this study. The use of both high-efficiency particulate air filter (HEPA) vacuums and trisodium phosphate (TSP) detergent are recommended by HUD, but there is limited evidence that these specifications are necessary for effective cleaning (12,13). The rationale behind using HEPA vacuums is based on the HEPA filter retaining all particles > 0.3 μm , therefore reducing the emission of particles by the vacuum that can resettle on cleaned surfaces. A Canadian study showed that the use of standard portable vacuum cleaners, without HEPA filters, can be associated with high levels of dust in the air. The dust can then resettle on the floor, providing some support for the HEPA filter requirement (14,15).

Although the HUD guidelines allow for the use of non-TSP detergents, they recommend the use of TSP (defined as a detergent with at least 5% trisodium phosphate) because of its supposed propensity to coat the surface of lead particles (here defined as particles with high lead content) with phosphate or polyphosphate groups, which thereby reduces electrostatic interactions with the surfaces and allows easier removal. In a recent laboratory study conducted by the U.S. EPA, however, TSP was no more effective than many low-phosphate household detergents in removing lead particles from various intact/smooth substrates, such as painted wood and linoleum

Address correspondence to D.Q. Rich, Harvard School of Public Health, Environmental Epidemiology Program, Building 1, Room 1414, 665 Huntington Avenue, Boston, MA 02111 USA. Telephone: (617) 432-1244. Fax: (732) 277-2382. E-mail: drich@hsph.harvard.edu

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(16). The substrates on which the detergents were compared may not be representative of those in older urban dwellings. Rich et al. (17), in a study comparing dust-lead sampling methods, found that TSP did not appear to remove lead particles selectively, because, although lead loading and dust loading levels decreased after cleaning with TSP, lead concentration did not. These studies, along with concern about the impact of phosphate waste on water quality and availability in urban retail stores, resulted in a recommendation by EPA to use other non-TSP detergents in cleaning protocols (18).

To determine whether TSP and HEPA vacuums are consistently and substantially superior to more readily available cleaning approaches, we performed a randomized trial to compare the HUD recommended cleaning method with two other less expensive methods.

Materials and Methods

Selection of study homes. We identified potential study homes either by referral from municipal lead-poisoning prevention programs or from responses to a mailing that was sent to families of children with elevated blood lead by the New Jersey Department of Health and Senior Services. Study staff scheduled a home visit with respondents to determine eligibility. Homes were eligible if *a*) they had a child with a blood lead level $> 10 \mu\text{g/dL}$ (index child), *b*) they had at least four windows accessible for sampling and cleaning, *c*) the index child had been residing in the home when the family first learned of the elevated blood lead level, and *d*) the family would remain in the home until a cleaning/sampling visit could be completed. As incentives parents received \$25 in grocery store gift certificates for an initial screening (first) visit and \$75 for the cleaning/sampling (second) visit. Informed consent was obtained for all study participants.

Randomization. Homes were randomly assigned to one of three cleaning methods by opening numbered, sealed envelopes. Assignments were arranged using a series of sequential randomized blocks of variable length (three or six houses). Within each block, assignments were made in a ratio of 1:1:1, so that at the end of each block, exactly one-third of the houses were assigned to each cleaning method. Randomization was done after the screening visit and before the cleaning/sampling visit to keep study personnel blinded while determining eligibility and surfaces to be sampled/cleaned. Personnel were not, however, blinded at the cleaning/sampling visit. We determined 135 homes to be eligible, of which 127 were cleaned. Residents of the eight homes not cleaned moved before the cleaning could be performed.

Cleaning procedures. Homes were cleaned according to the hard surfaces protocol

recommended in the HUD guidelines as an interim measure for removing lead-contaminated dust (11) using one of the following combinations of detergent and vacuum: *a*) TSP detergent and a Nilfisk GS80 HEPA vacuum (Malvern, PA), *b*) TSP and a Eureka World Vacuum model 6865 (Bloomington, IL) with no HEPA filter, or *c*) Spic 'n' Span (non-TSP) and Eureka World Vacuum model 6865 with no HEPA filter (selected based on its retail availability throughout northern New Jersey). Each surface was vacuumed (at $1\text{--}3 \text{ min/m}^2$) and then wet washed with the detergent. A minimum of two complete rooms and two other windows, with surrounding areas, were cleaned in each home (a total of four rooms/windows). We used the same method for all surfaces cleaned within a home.

Sampling procedures. The protocol for HUD dust-wipe sampling has been described elsewhere (19). HUD dust-wipe samples were taken on four window sills, two window troughs, and two hard floors throughout the house. We sampled a larger number of window sills per home, compared to floors and window troughs, to increase the power to detect a pre-/postcleaning difference in lead loading. Study staff chose these sampling sites based on their accessibility to the child. Only one window was sampled per room, if possible. The kitchen was generally included as one of the four rooms to be sampled. Pre- and postcleaning samples were taken directly adjacent to each other, with postcleaning samples taken at least 1 hr after cleaning to allow suspended dust to settle.

Laboratory analysis. Each baby wipe towlette was placed in a 120 mL digestion liner with 20 mL of concentrated nitric acid (trace metal grade, lead $< 0.1 \text{ ppb}$, Fisher Scientific, Edison, NJ). The liners were placed in the turntable with vessels open overnight. The samples were microwave digested (microwave oven: CEM MDS-2000; CEM, Matthews, NC) and then allowed to cool for at least 2 hr. The samples were then filtered (1541 150 hardened ashless circle; Whatman, Clifton, NJ) and transferred to 50-mL tubes (conical bottom, Corning free-standing 50-mL plastic tubes; Corning, NY) and diluted to 50 mL with deionized water.

We determined lead concentrations (micrograms per gram) of HUD dust wipes by using flame atomic absorption spectrometry (FAA; Perkin-Elmer 3100, Norwalk, CT) at a wavelength of 283.3 nm. The detection limit of the FAA was $0.5 \mu\text{g/mL}$ in solution. Graphite furnace atomic absorption spectrophotometry (GFAA; Perkin-Elmer Zeeman 5100), with a detection limit of $2.5 \mu\text{g/L}$ in solution, was used to analyze samples that were below the detection limit of the FAA. Both FAA and GFAA were calibrated for each

run with standards prepared from optima grade nitric acid (Fisher Scientific). The National Institute of Standardized Testing (NIST; Gaithersburg, MD) reference materials 2709 (the San Joaquin soil with Pb concentration of 18.9 mg/kg) and 2711 (the Montana soil with Pb concentration of 1162 mg/kg ; NIST) were digested and used as internal quality assurance checks for all sample runs on FAA. The NIST 1643d (Pb dissolved in water with a concentration of $18.15 \pm 0.64 \mu\text{g/L}$, density of the solution = 1.016 g/mL at 22°C) was used for quality control at each run of the GFAA analysis. Sample digestion blanks, reagent blanks, and lead solution spikes were included in all analytical runs. Acceptable instrument error was within $\pm 20\%$, although most quality control analyses were within $\pm 10\%$.

Statistical analysis. We entered the values below the minimum detection limit (MDL) of the GFAA ($0.25 \mu\text{g/sample}$) as $\text{MDL}/2$ or $0.125 \mu\text{g/ft}^2$ to include the sample in the analysis. Because our laboratory does not participate in the Centers for Disease Control and Prevention-sponsored quality control program for lead, we conducted an interlaboratory comparison where samples ($n = 52$) spiked with known lead values were analyzed at our laboratory. The results from our laboratory analysis correlated well with those from the reference laboratory ($r = 0.97$; $p = 0.001$). However, there was a systematic difference between the two laboratories' results. We adjusted for this for all values $> 3 \mu\text{g/sample}$ using the following formula: corrected value = $[(\text{laboratory value} \times 1.31) - 0.85]/\text{sampling area}$ (floors = 1 ft^2 , sills and troughs variable). Values were then log transformed to reduce skewness. Statistical analyses were conducted separately for hard floors, window sills, and window troughs. To assess the effectiveness of each cleaning method on surfaces with low and high dust lead loading levels, each surface type (floor, window sill, or window trough) was stratified into samples above or equal to the HUD standards ($40 \mu\text{g/ft}^2$ on floors, $250 \mu\text{g/ft}^2$ on sills, and $800 \mu\text{g/ft}^2$ on troughs) and those below the HUD standard (at the time of the statistical analysis, the window trough clearance standard was $800 \mu\text{g/ft}^2$).

We used mixed models (a repeated-measures analysis using SAS PROC MIXED, version 8; SAS Institute Inc., Cary, NC) to account for the correlation of samples within a home (two floors, four sills, and two wells). A mixed model was fit separately for each of the three *a priori* comparisons of interest: *a*) TSP/HEPA versus TSP/non-HEPA to compare HEPA and non-HEPA vacuum cleaners, *b*) TSP/non-HEPA versus non-TSP/non-HEPA to compare TSP and non-TSP detergents, and *c*) TSP/HEPA (HUD method) versus non-TSP/non-HEPA.

In each model, log change in lead loading was the outcome variable and method was the independent variable. Each model was then refit adding log of precleaning lead loading as an independent variable to adjust for differences in baseline lead loading.

Results

All three cleaning methods made significant reductions in lead loading from pre- to postcleaning ($p < 0.0001$) on hard floors, window sills, and window troughs. There were unexpected, substantial precleaning differences in geometric mean lead loading among the groups (repeated-measures, mixed-model analysis; floors $p = 0.0036$, sills $p = 0.3099$, troughs $p = 0.0032$; Table 1). We could identify no defects in the randomization process and believe the lower levels of contamination in the homes assigned to the TSP/HEPA intervention were entirely due to chance.

All cleaning methods achieved substantial reduction in lead loadings. Postcleaning geometric means were much more similar than the precleaning values, but in each case the lowest levels were achieved by the TSP/HEPA combination. However, the percent reduction for floors achieved by the TSP/HEPA method was actually less than that achieved by the other two methods. Thus, it was not clear whether the lower postcleaning values in homes cleaned by the TSP/HEPA method might be related to the lower level of initial contamination in the houses assigned to that group rather than to greater efficiency of the method.

To address this issue and to focus attention on the surfaces that exceeded HUD clearance standards, we repeated the descriptive analysis for the 60% of surfaces that were above these standards at baseline (Table 2). The precleaning levels, the postcleaning levels, and the percent reduction achieved in the geometric means were all much more similar among the cleaning methods in this restricted data set.

The distribution of substrate types on floors and window sills (linoleum, painted wood, metal, plastic, bare wood, and the like) did not differ substantially among the randomized groups. Homes treated by the TSP/HEPA (HUD) method had more plastic window troughs and fewer painted wood window troughs than those treated with either the TSP/non-HEPA method or the non-TSP/non-HEPA method (Table 3). Most hard floors were either linoleum (53–67%) or painted wood (22–38%). Only a few floors were bare wood (0–5%). Window sills were predominantly painted wood (92–96%), and window troughs were a variety of surfaces.

There did not appear to be substantial differences in the condition of the substrates (intact, minor problems, or deteriorated) by

method. On floors, 89% of the samples from the TSP/HEPA cleaned floors were intact (defined as no visible paint chips and minimal if any damage to substrate), and 93% and 97% of the TSP/non-HEPA and non-TSP/non-HEPA samples, respectively, were intact. On window sills, 60%, 66%, and 71% of the TSP/HEPA, TSP/non-HEPA, and non-TSP/non-HEPA samples, respectively, were intact, and 37%, 31%, and 28% had minor problems (defined as a small to moderate amount of nonintact surface area). On window troughs, 67%, 63%, and 81% of the TSP/HEPA, TSP/non-HEPA, non-TSP/non-HEPA sampling surfaces, respectively, were intact, whereas 18%, 21%, and 10%, respectively, had minor problems. Among those sample pairs within each method with postcleaning samples above the clearance standard, the postcleaning samples were not more likely to be classified as “deteriorated” (defined as more than 50% of the surface nonintact) than their precleaning matches. This was true for floor, sill, and trough samples. This suggests that the cleaning procedure did not adversely alter the sub-

strate surface, causing the surface to fail clearance. Also, most postcleaning samples classified as deteriorated (2.3% of floors, $n = 5$; 2.1% of window sills, $n = 10$; 14% of window troughs, $n = 30$), were also above clearance levels ($n = 4$ floors, $n = 3$ window sills, $n = 27$ window troughs), demonstrating the importance of substrate stabilization.

To make adjusted comparisons among the cleaning methods and estimate effect sizes, we used a mixed model, which was applied to the log-transformed data. Because there did not seem to be major differences in the substrates across the intervention groups, we did not model substrate variables. Thus, the only adjustment added to the randomized comparison is the differences in lead contamination at baseline.

Several comparisons resulting from this analysis, when applied to the entire data set, are shown in Table 4. On floors the non-HEPA vacuum cleaner produced 19% [95% confidence interval (CI), 3–38%] larger reductions than the HEPA vacuum cleaner. On window sills, the HEPA vacuum cleaner produced 22% (95% CI, 11–32%) larger

Table 1. Descriptive statistics of pre- and postcleaning lead loading ($\mu\text{g}/\text{ft}^2$) by sampling surface type and cleaning method.

Surface and method	Precleaning GM	Within-home GSD	Between-home GSD	Postcleaning GM	Within-home GSD	Between-home GSD	Percent reduction in GM ^a
Floors							
TSP/HEPA ($n = 70$)	26.7	1.96	4.44	13.8	2.25	4.16	48
TSP/non-HEPA ($n = 80$)	65.2	2.74	5.29	18.0	2.30	4.25	72
non-TSP/non-HEPA ($n = 67$)	52.0	2.27	4.70	17.3	2.33	4.47	67
Sills							
TSP/HEPA ($n = 155$)	2.90×10^2	4.22	5.63	0.484×10^2	3.22	6.35	83
TSP/non-HEPA ($n = 173$)	3.74×10^2	3.57	4.50	1.04×10^2	3.90	5.03	72
non-TSP/non-HEPA ($n = 156$)	2.71×10^2	2.89	5.36	0.981×10^2	3.79	6.08	64
Troughs							
TSP/HEPA ($n = 67$)	1.36×10^3	3.06	25.5	1.34×10^2	2.71	14.5	90
TSP/non-HEPA ($n = 75$)	3.22×10^3	2.64	6.98	4.68×10^2	3.73	11.2	85
non-TSP/non-HEPA ($n = 72$)	5.06×10^3	2.40	6.93	4.78×10^2	3.39	9.43	91

Abbreviations: GM, geometric mean; GSD, geometric standard deviation.

^aPercent reduction in GM = [(precleaning GM – postcleaning GM)/precleaning GM] \times 100.

Table 2. Descriptive statistics of pre- and postcleaning lead loading ($\mu\text{g}/\text{ft}^2$) by sampling surface type and cleaning method.

Surface and method	Precleaning GM	Within-home GSD	Between-home GSD	Postcleaning GM	Within-home GSD	Between-home GSD	Percent reduction in GM ^a
Floors							
TSP/HEPA ($n = 32$)	1.04×10^2	1.50	1.93	33.4	1.71	2.96	68
TSP/non-HEPA ($n = 48$)	2.00×10^2	2.37	3.50	43.1	2.28	3.23	78
non-TSP/non-HEPA ($n = 40$)	1.55×10^2	2.18	2.57	39.2	1.85	4.59	75
Sills							
TSP/HEPA ($n = 88$)	1.38×10^3	2.60	2.52	1.70×10^2	2.93	4.93	88
TSP/non-HEPA ($n = 101$)	1.36×10^3	2.63	2.55	3.20×10^2	3.63	3.08	76
non-TSP/non-HEPA ($n = 87$)	1.09×10^3	2.28	2.26	3.36×10^2	2.51	4.56	69
Troughs							
TSP/HEPA ($n = 37$)	10.0×10^3	2.28	4.06	0.811×10^3	3.26	10.2	92
TSP/non-HEPA ($n = 58$)	7.77×10^3	2.18	3.83	1.19×10^3	3.55	7.17	85
non-TSP/non-HEPA ($n = 58$)	10.3×10^3	2.03	4.40	1.03×10^3	3.19	6.97	90

Only precleaning samples > HUD clearance level (floors = $40 \mu\text{g}/\text{ft}^2$, sills = $250 \mu\text{g}/\text{ft}^2$, troughs = $800 \mu\text{g}/\text{ft}^2$). Abbreviations: GM, geometric mean; GSD, geometric standard deviation.

^aPercent reduction in GM = [(precleaning GM – postcleaning GM)/precleaning GM] \times 100.

reductions than the non-HEPA vacuum cleaner, and on the window troughs it produced 16% (95% CI, -4 to 33%) larger reductions than the non-HEPA vacuum cleaner. TSP produced 5% (95% CI, -12 to 19%) larger reductions than non-TSP on floors, and 8% (95% CI, -5 to 20%) larger reductions on window sills, whereas non-TSP produced 21% (95% CI, -2 to 50%) larger reductions than TSP on window troughs. When we compared the HUD method (TSP/HEPA) and the non-TSP/non-HEPA, the HUD method produced 28% (95% CI, 18–37%) larger reductions on window sills, and 2% (95% CI, -24 to 23%) larger reductions on window troughs. The non-TSP/non-HEPA method produced 13% (95% CI, -5 to 34%) larger reductions than the HUD method on hard floors (Table 4).

To assess whether we had controlled fully for baseline lead loading in our mixed-model analysis (i.e., was the effect of cleaning linear in relation to baseline lead loading?), we ran another set of mixed models using only those sample pairs with a baseline lead loading

above the HUD clearance standards. The same variables were included. None of the nine comparisons shown in Table 4 reversed direction, suggesting that the cleaning effect is similar for the higher lead levels. Therefore, our mixed models appear to control adequately for baseline lead loading.

Discussion

Because each cleaning method substantially reduced lead loading, it is clear that any of these cleaning methods is better than no cleaning. Baseline lead loading levels appear to be similar to those found in other regional (northeastern United States) studies of high-risk urban homes (8,17,20,21), and the distribution of substrate types and conditions is also consistent with prior work (22).

Although crude results suggested that the TSP/HEPA method was more efficient at bringing those homes above HUD guidance levels at baseline under clearance after cleaning, there were substantial differences in baseline means. The TSP/HEPA method's precleaning geometric mean was the lowest in two of the

three sample types. With baseline values closer to the HUD guidance levels, the TSP/HEPA method, as expected, brought a greater proportion of these homes under clearance levels. To properly make comparisons, these differences in baseline lead loadings were entered as independent variables in the mixed models.

Although the HEPA vacuum cleaner was significantly better at reducing lead loading on window sills after adjusting for baseline levels, the non-HEPA vacuum cleaner produced larger reductions on uncarpeted floors. Because it is not significantly better than the non-HEPA vacuum cleaner on hard surfaces, inclusion of a HEPA vacuum cleaner in cleaning protocols may be important only for its ability to make larger reductions on carpeted floors. The HEPA vacuum cleaner used in this study has more suction power (87 ft³/min reported by Nilfisk, Inc.) than the non-HEPA vacuum cleaner (66.3 ft³/min tested by Inter Basic Resources, Inc., Grass Lake, MI) and may therefore be more effective in pulling particles out of carpets. This difference in suction power may not matter as much on hard surfaces, which generally have smaller surface areas (i.e., no fibers) and fewer electrostatic interactions than carpets. On carpeted floors, this extra suction power may be necessary to remove particles trapped by electrostatic forces within a densely packed carpet pile. Also, re-entrainment and subsequent settling of particles, by the non-HEPA vacuum cleaner, onto hard floors does not appear to be a problem because of the wet mopping done immediately after vacuum cleaning. There does not appear to be a clear difference between the HEPA and non-HEPA vacuum cleaner on hard surfaces, and the non-HEPA vacuum cleaner appeared more efficient in removing particles on uncarpeted floors, which is the hard surface that may best reflect exposure to children.

When TSP or non-TSP was used in combination with the non-HEPA vacuum cleaner, and after adjusting for baseline lead loading levels, both detergents produced similar reductions on all surfaces, with TSP producing slightly larger reductions on floors and sills and non-TSP producing a larger reduction on window troughs. The theoretical ability of high-phosphate detergents (TSP) to selectively bind lead particles did not provide any clear advantage over the more readily available low-phosphate detergent (non-TSP). It is likely that the frequency, duration, and thoroughness of the cleaning are more important determinants of residual lead contamination than the choice of detergent.

Neither the HUD method (TSP/HEPA) nor our alternative non-TSP/non-HEPA method was clearly superior for removing lead dust from hard floors, window sills, or window troughs. This is consistent with the

Table 3. Percentage of samples of each substrate type by sample type and cleaning method.

Substrate	TSP/HEPA	TSP/non-HEPA	non-TSP/non-HEPA
Floors			
No.	70	80	67
Linoleum (%)	63	53	67
Painted wood (%)	30	38	22
Tile (%)	7	5	6
Bare wood (%)	0	5	4
Window sills			
No.	155	173	156
Painted wood (%)	95	92	96
Bare wood (%)	1	6	1
Other (%)	4	2	
Window troughs			
No.	67	75	72
Painted wood (%)	28	47	49
Bare wood (%)	3	9	4
Plastic (%)	52	31	22
Metal (%)	13	11	22
Other (%)	3	3	3

Table 4. Difference in mean percent change in lead loading and 95% CIs (in parentheses).

Comparison	Floors	Sills	Troughs
HEPA vs. non-HEPA	non-HEPA 19% (3–38%) larger reduction than HEPA ^a	HEPA 22% (11–32%) larger reduction than non-HEPA ^a	HEPA 16% (-4–33%) larger reduction than non-HEPA ^a
TSP vs. non-TSP	TSP 5% (-12–19%) larger reduction than non-TSP ^b	TSP 8% (-5–20%) larger reduction than non-TSP ^b	non-TSP 21% (-2–50%) larger reduction than TSP ^b
HUD method vs. non-TSP/non-HEPA method	non-TSP/non-HEPA 13% (-5–34%) larger reduction than HUD ^c	HUD 28% (18–37%) larger reduction than non-TSP/non-HEPA ^c	HUD 2% (-24–23%) larger reduction than non-TSP/non-HEPA ^c

Adjusted for precleaning log lead loading.

^aMixed model generated a coefficient (β_{HEPA}) comparing relative reduction in lead loading for HEPA vacuum vs. non-HEPA vacuum. For example: computation = $\exp(\beta_{HEPA}) = \exp(0.1728) = 1.19$ = HEPA vacuum postcleaning level is 119% of the non-HEPA vacuum. Therefore, non-HEPA vacuum has a 19% larger reduction than HEPA vacuums. ^bMixed model generated a coefficient (β_{TSP}) comparing relative reduction in lead loading for TSP vs. non-TSP. For example: computation = $\exp(\beta_{TSP}) = \exp(-0.0513) = 0.95$ = TSP postcleaning level is 95% of non-TSP. Therefore, TSP has a 5% larger reduction than non-TSP. ^cMixed model generated a coefficient (β_{HUD}) comparing relative reduction in lead loading for HUD method vs. non-TSP/non-HEPA method. For example: computation = $\exp(\beta_{HUD}) = \exp(0.1222) = 1.13$ = HUD method postcleaning level is 113% of the non-TSP/non-HEPA method. Therefore, non-TSP/non-HEPA method has a 13% larger reduction than HUD method.

absence of an advantage for either TSP detergent or the HEPA vacuum cleaner separately. It appears that the use of properly operating non-HEPA vacuum cleaners and low-phosphate detergents may be just as effective in reducing lead loading on hard surfaces as the HUD-recommended method for interim control. It is likely that these findings would extend to other similar non-HEPA vacuum cleaners and household detergents.

Conclusions and Recommendations

Although TSP was recommended as part of the HUD guidelines because of its expected chemical advantages, its inclusion does not seem necessary; the low-phosphate detergent tested appears to perform comparably. The HEPA vacuum cleaner's filtering advantages over the non-HEPA vacuum cleaner did not provide any substantial benefit in cleaning on hard surfaces in this study, and any ability to achieve larger reductions on window troughs may be due to suction power or a vacuum cleaner's structural characteristics (e.g., nozzle size or shape), rather than some inherent feature of the HEPA filtering mechanism. Vacuum cleaner performance may be improved by replacing filter bags before they become completely full or by using improved filtration or "allergy" filter bags. Frequency, duration, substrate cleanability, and thoroughness of cleaning are important components of a cleaning strategy to stress to the public. More

control of lead-contaminated dust may be achieved by encouraging the use of readily available and less expensive detergents and vacuum cleaners than by emphasizing the need of special cleaning equipment and supplies.

REFERENCES AND NOTES

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